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Бардин Д.Ю., Федоренко О.М., Шумейко Н.М. **E2 - 12564**

О радиационных поправках к P-нечетной асимметрии в глубоконеупругом рассеянии поляризованных лептонов на нуклонах

В рамках кварк-партонной модели и модели Вайнберга-Салама впервые вычислена радиационная поправка к P-нечетной асимметрии в глубоконеупругом рассеянии лептонов на нуклонах.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1979

Bardin D.Yu., Fedorenko O.M., Shumeiko N.M. **E2 - 12564**

On the Radiative Corrections to P-Odd Asymmetry in Deep-Inelastic Scattering of Polarized Leptons on Nucleons

Based on the simple quark-parton model of strong interaction and on the Weinberg-Salam theory, the radiative corrections to the P-odd asymmetry in deep-inelastic scattering of polarized leptons on unpolarized nucleons are calculated. It is shown that the radiative effect reaches 20% at some kinematical points, but does not exceed 10% in the region of the SLAC experiment.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

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The recent discovery of P-odd asymmetry in deep-inelastic scattering of longitudinally polarized electrons on deuterons by the Stanford group [1] has completed an important step in experimental investigation of the weak neutral current structure. All neutral current data are now well-consistent with the $SU(2)\otimes U(1)$ gauge theory by Salam and Weinberg [2].

There exist now some proposals to measure P-odd asymmetries at high q^2-values in μN-deep-inelastic scattering [3].

The theoretical analysis of P-odd asymmetries was performed so far in the Born approximation [4]: only the interference of one-gamma with one - Z exchange diagrams was taken into account [4]. For the case of scattering on an isoscalar target, neglecting the isoscalar current contribution, the model-independent analysis for asymmetries $A^{\mp}$ reads (at $\sin^2\theta_W = 1/4$)

$$A^{\mp} = \frac{1}{\lambda}[(d^2\sigma^{\mp})_{\lambda} - (d^2\sigma^{\mp})_{-\lambda}]/[(d^2\sigma^{\mp})_{\lambda} + (d^2\sigma^{\mp})_{-\lambda}] \simeq \mp 9\cdot 10^{-5} q^2 \mathrm{GeV}^{-2}, \qquad (1)$$

where λ is the longitudinal polarization of initial leptons, q^2 the transfer momentum squared, and $d^2\sigma$ the differential cross section of considered processes. The isoscalar contribution can be taken into account within the parton model where one obtains the following expression for $A_0^{\mp}$

$$A_0^{\mp} = \mp \frac{q^2}{4M_W^2 \sin^2\theta_W}\left[\frac{9}{10} - 2\cdot\sin^2\theta_W \pm \frac{9}{10}\cdot(1-4\sin^2\theta_W)R(y)\right], \qquad (2)$$

with $R(y)=y(2-y)/T_0$, $T_0=1+(1-y)^2$. M_W is the W-boson mass. At $\sin^2\theta_W=1/4$ $M_W=74.6$ GeV and from (2) we have

$$A_0^{\mp}=\mp\frac{2}{5}\cdot q^2/M_W^2\simeq \mp 7{,}2\cdot 10^{-5}\,q^2\cdot \mathrm{GeV}^{-2}. \qquad (3)$$

In this note we calculate the lowest-order radiative corrections (RC) to eq. (2). To calculate the lowest order RC within a gauge theory, it is necessary to perform the renormalization program, which in turn requires the calculation of all one-loop diagrams [5].

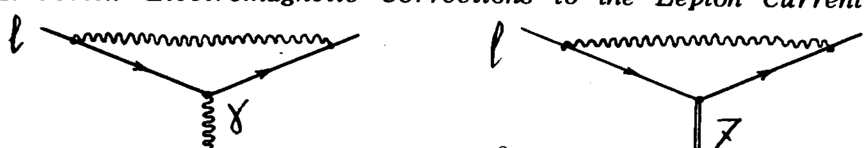
While calculating the differential cross section $d^2\sigma_1$ within one-loop approximation in the parton model we are forced to consider quarks as free particles on mass-shell [6]. It is evident, that it is difficult to estimate the extent of applicability of such an approach. The calculations exhibit, however, a rather favourable situation. Let us calculate two asymmetries. The first one, A_1 is derived from the differential cross section $d^2\sigma_1$; while calculating it we take into account all one-loop diagrams and realize the whole renormalization program. The second one, $\bar{A}_1$ is derived from $d^2\bar{\sigma}_1$; in its calculation we leave only finite parts of a small number of diagrams, which can be treated within the parton model unambiguously. The result is

$$\left|\frac{A_1-\bar{A}_1}{A_0}\right| < 0{,}2\left|\frac{A_1-A_0}{A_0}\right|. \qquad (4)$$

If l.h.s. of this inequality is regarded as an estimation of inaccuracy in the calculation of the RC to asymmetry, ineq. (4) means that this inaccuracy is much smaller than the RC itself.

Below we list the contributions to $d^2\bar{\sigma}_1$ from the diagrams which are taken into account in the calculation of $d^2\bar{\sigma}_1$.

I. Vertex Electromagnetic Corrections to the Lepton Current



$$d^2\sigma_V=(d^2\sigma_0^A+d^2\sigma_0^Z)\cdot\frac{\alpha}{\pi}\cdot\left(\frac{3}{2}\ln\frac{q^2}{m^2}-2\right), \qquad (5)$$

$$\frac{d^2\sigma_0^A}{dx\,dy}=K\cdot\sum_i x\,f_i(x)Q_i^2 ,$$

$$\frac{d^2\sigma_0^{Z\mp}}{dx\,dy}=K\cdot\frac{q^2}{8M_W^2\sin^2\theta_W}\sum_i x f_i(x)|Q_i|\cdot[b_i(a\mp\lambda)+(\pm 1-a\lambda)R(y)],$$

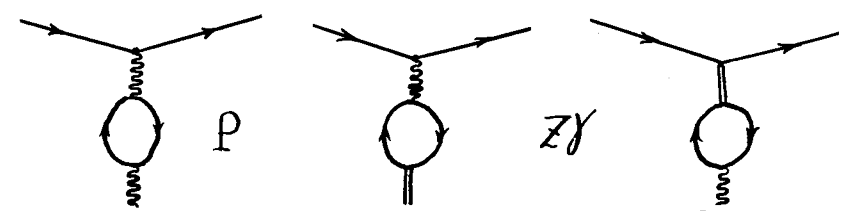
$$K=\frac{2\pi\cdot\alpha^2\cdot S_N}{q^4}\cdot T_0 , \qquad (6)$$

where $S_N=2M_NE$, M_N is the nucleon mass, m is the lepton mass, E is an energy of the initial lepton in lab.syst., x and y are usual scaling variables, Q_i is the i-th quark charge, $f_i(x)$ is the i-th quark momentum distribution (in numerical calculations we employ spectra from ref. [7]), $\alpha\simeq 1/137$, $a=1-4\sin^2\theta_W$,

$$b_i=1-4|Q_i|\sin^2\theta_W,\ \sin^2\theta_W=4\pi\alpha/g_F^2,\ \sqrt{2}\cdot\frac{g_F^2}{8M_W^2}=10^{-5}\cdot\frac{1{,}0245}{M_P^2}\ ^{*}.$$

In summing over partons types i in (6) and below, we take into account only contributions from valence u-and d-quarks.

II. Vacuum Polarization Including $Z\gamma$-Mixing



$$d^2\sigma_P=(d^2\sigma_0^A+d^2\sigma_0)\cdot\frac{\alpha}{4\pi}\cdot G(q^2),\qquad d^2\sigma_0=d^2\sigma_0^A+d^2\sigma_0^Z , \qquad (7)$$

$$\frac{d^2\sigma_{Z\gamma}^{\mp}}{dx\,dy}=\frac{\alpha^3\cdot S_N}{4q^2M_W^2}T_0\cdot D(q^2)\sum_i x f_i(x)|Q_i|[-(b_i+a|Q_i|)+\lambda(R(y)\pm|Q_i|)], \qquad (8)$$

$$G(q^2)=\frac{4}{3}\sum_f Q_f^2\left(\ln\frac{q^2}{m_f^2}-\frac{5}{3}\right), \qquad (9)$$

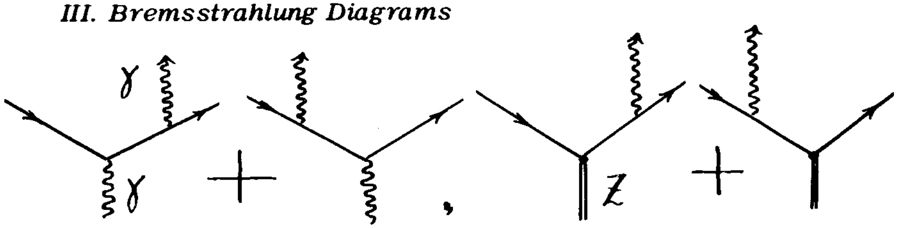
$$D(q^2)=G(q^2)-\frac{1}{3\sin^2\theta_W}\cdot\left(\ln\frac{q^2}{M_W^2}-\frac{5}{3}\right)\sum_f|Q_f|.$$

---

* g_F is the physical constant of "semiweak" interaction [9].

Summing in (9) extends over all charged fermions $e, \mu, Q, \ldots$ which can appear in vacuum loops. In numerical calculations we take into account e, μ, u and d loops. Leaving u- and d-loops we approximate to some extent the contribution of hadron vacuum polarization[8]. The contributions from heavy leptons and heavy quarks are rather smaller than the considered ones.

III. Bremsstrahlung Diagrams



For the contribution of these diagrams to the cross section we write the usual representation[6]

$$d^2\sigma_R = \frac{\alpha}{\pi}\cdot\delta\cdot d^2\sigma_0 + d^2\sigma_D + d^2\sigma_R^F, \tag{10}$$

$$d^2\sigma_D = \frac{\alpha}{\pi}\cdot \mathcal{J}(q^2)\cdot d^2\sigma_0\Big|_{xf_i(x)\to} \int_x^1 \frac{\xi f_i(\xi) - x f_i(x)}{\xi - x}\, d\xi, \tag{11}$$

$$\delta = -\frac{1}{2}\ln^2(1-y) - \frac{1}{2}\mathcal{J}(q^2)\ln\frac{x^2(1-y)}{y^2(1-x)^2}, \qquad \mathcal{J}(q^2) = 2\left(\ln\frac{q^2}{m^2} - 1\right). \tag{12}$$

The contribution to $d^2\sigma_R^F$ from the first two diagrams squared was calculated in[6], it reads

$$\left(\frac{d^2\sigma_R^F}{dx\,dy}\right)_{\gamma\gamma} = 2\alpha^3 y \sum_i Q_i^2 \int_x^1 f_i(\xi)\frac{d\xi}{\xi}[\Phi^i(S;X) + \Phi^i(-X,-S)],$$

$$\Phi^i(S;X) = -\frac{1}{2(S-q^2)}\ln\frac{(S-q^2)^2}{m^2\tau_i} + \frac{1}{2S_X}\cdot\ln\frac{(S_X V + m_{Q_i}^2 q^2)^2}{m_{Q_i}^2 q^4 \tau_i} - \frac{1}{q^2}\cdot\left(\ln\frac{q^2}{m^2} - 1 + \frac{V(S^2+X^2)}{2SX\cdot q^2}\right) - \frac{2}{X\cdot q^2}\left(S - \frac{q^2}{2} - \frac{S^2+X^2}{q^2}\right)\ln\frac{X}{m\cdot m_{Q_i}}, \quad \tau_i = V + m_{Q_i}^2, \quad V = S_X - q^2, \tag{13}$$

$S_X = S - X$, $S = \xi\cdot S_N$, $X = \xi\cdot S_N(1-y)$, m_{Q_i} is the i-th quark mass. The contribution to $d^2\sigma_R^F$ from the interference of first two diagrams with the last two ones is

$$\left(\frac{d^2\sigma_R^F}{dx\,dy}\right)_{Z\gamma}^{\mp} = \frac{\alpha^3 y}{4M_W^2\sin^2\theta_W}\sum_i |Q_i| \int_x^1 f_i(\xi)\frac{d\xi}{\xi}\cdot[\theta_+^{i\mp}\cdot F_i(S;X) - \theta_-^{i\mp}\cdot F_i(-X;-S)],$$

$$F_i(S;X) = 1 + \frac{2S}{q^2} - \left(1 + \frac{S+X}{q^2}\right)\ln\frac{q^2}{m^2} + \frac{1}{2(S-q^2)}\Big[X + q^2 + \frac{2xq^2}{S-q^2} - \left(X + q^2 + \frac{S\cdot X}{S-q^2}\right)\ln\frac{(S-q^2)^2}{m^2\tau_i}\Big], \tag{14}$$

$$\theta_+^{i\mp} = \pm 1 - a\lambda + b_i(a\mp\lambda), \quad \theta_-^{i\mp} = \pm 1 - a\lambda - b_i(a\mp\lambda).$$

Summing I-III we obtain the final expression for $d^2\bar{\sigma}_1$

$$d^2\bar{\sigma}_1 = d^2\bar{\sigma}_0 + d^2\sigma_V + d^2\sigma_P + d^2\sigma_{Z\gamma} + d^2\sigma_R. \tag{15}$$

Inserting this cross section in eq. (1) we derive asymmetry $\bar{A}_-^1$ for the scattering on the isoscalar nucleon.

In *fig. 1* asymmetry $\bar{A}_-^1$ is presented for deep inelastic μN-scattering at incident muon energy 280 *GeV* as a function of y at three fixed q^2= 100, 200, 300 *GeV*^{2}. Dotted lines repre-

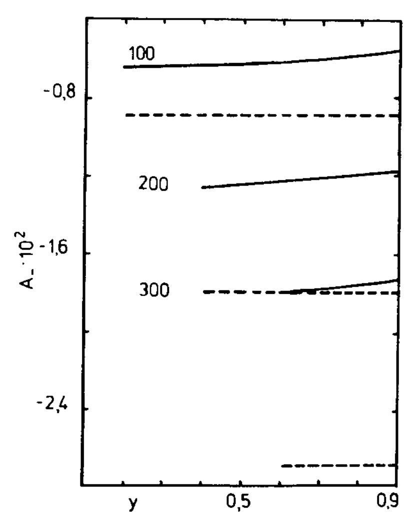


Fig. 1

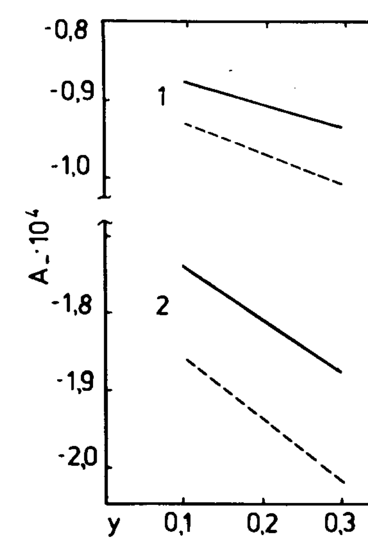


Fig. 2

sent the model-independent prediction (1). It is seen that RC reaches 20% of the value (3). Both the RC and isoscalar contributions reduce the prediction (3), therefore, the difference between $\bar{A}^1_-$ and (3) reaches 40%.

In *fig. 2* $\bar{A}^1_-$ is given for the case of eN-scattering in the kinematical region of experiment /1/ (E= 20 *GeV*, $0.1 \lesssim y \lesssim 0.3$, $q^2 \approx 1{,}2$ *GeV*^{2} and $\sin^2\theta_W \approx 1/5$) together with the parton-model prediction (2) (dotted line). In this region RC to A_0^- does not exceed 10%.

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